Symbiotic Stars as Laboratories for the Study of Accretion and Jets: A Call for Optical Monitoring

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Abstract Symbiotic binary stars typically consist of a white dwarf (WD) that accretes material from the wind of a companion red giant. Orbital periods for these binaries are on the order of years, and their relatively small optical outbursts tend to occur every few years to decades. In some symbiotics, material that is transferred from the red giant to the WD forms a disk around the WD. Thus, symbiotic stars are a bit like overgrown cataclysmic variables (CVs), but with less violent eruptions. Symbiotic stars are not as well understood as CVs, in part because their longer variability time scales mean that observations over many years are required to cover different outburst states and orbital phases. The recent discovery of collimated outflows ("jets") from a number of symbiotics provides a new motivation for such long-term study of these objects. Astrophysical jets are observed in almost every type of accretion-powered system, and symbiotic stars may help us understand these structures. In symbiotics, most jets appear to be associated with optical eruptions. Optical monitoring by amateurs can identify systems in outburst, and also help to build a comprehensive database of outburst and quiescent symbiotic light curves. Together with radio through X-ray observations that will be performed when new outbursts are found, long-term optical light curves will improve understanding of symbiotic outbursts, jet production, and the connection between outbursts, jets, and accretion disks in symbiotic stars.

1. Introduction: What are symbiotic stars?

Symbiotic stars are interacting binary stars in which a hot white dwarf (WD; or in a few cases a main-sequence star) orbits a red-giant star and captures material from the wind of the red giant (RG). A schematic diagram of the main components of a symbiotic binary is shown in Figure 1. Because a WD is compact (roughly the size of the earth, but with the mass of the sun), it has a strong gravitational field and can capture more of the wind than would otherwise hit the WD directly. As the accreted wind material falls toward the WD, it is accelerated and heated, and energy is released. In some symbiotic binaries, the accreted material may form a disk around the WD. Figure 2 is a computer-generated picture (not to scale) of the two stars, including an accretion disk and a bi-polar (i.e., two-sided) jet (discussed in Section 2). Symbiotic stars are thus similar to cataclysmic variable stars (CVs). However, whereas a typical CV binary is not much larger than our sun, the distance between

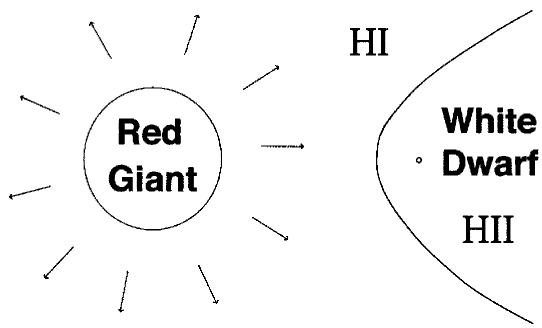

Figure 1. Schematic drawing of the main components of a symbiotic binary: the hot white dwarf (small circle on the right of the diagram), the cool red giant losing material in a wind, and the partially ionized nebula. In this picture, the bow-shaped curve represents the boundary between the portion of the nebula that is ionized by radiation from the hot WD (ionized hydrogen is designated HII), and the region that is primarily neutral hydrogen (HI). In different systems, this boundary can have different shapes.

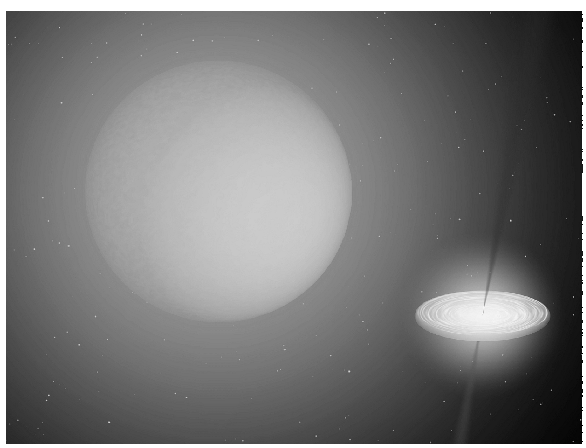

Figure 2. This computer-generated picture shows the components believed to comprise a jet-producing symbiotic binary (except the extended nebula): a large red-giant star losing material in a wind, and a compact white dwarf surrounded by an accretion disk. The accreting WD may occasionally produce a collimated jet. *Image courtesy R. Hynes.*

the stellar components in a standard symbiotic binary is comparable to the distance between the earth and the sun.

Symbiotic stars are also closely related to the other main type of accreting-white-dwarf binary: supersoft X-ray sources. If the accretion rate onto the white dwarf in a symbiotic binary is within a certain range, the temperature and pressure at the base of the layer of accreted hydrogen-rich material will be very high. The hydrogen may then undergo quasi-steady nuclear fusion burning (Paczyński and Żytków 1978; Fujimoto 1982), causing additional energy to be released. Optical, UV, and X-ray spectra, as well as the reduced amplitude of rapid optical flickering from an accretion disk (usually so low it is undetectable), compared to that in CVs, support the idea that nuclear burning on the surface of the white dwarf is the dominant source of power in most symbiotics (e.g., Mürset *et al.* 1991; Sokoloski, Bildsten, and Ho 2001). Such quasi-steady nuclear burning on the surface of a white dwarf is also thought to power supersoft X-ray sources (van den Heuvel *et al.* 1992).

Most of the wind from the red giant in a symbiotic binary is not accreted onto the WD. Instead, it forms a large nebula around the binary that is partially ionized by radiation from the accreting WD and the nuclear fusion on its surface. The ionized nebula radiates in the optical, and thereby conveys information about the X-ray- and far-ultraviolet-emitting WD into the optical regime. Symbiotic optical spectra thus show both absorption lines from the surface of the cool red giant, and nebular emission lines that require the presence of a hot source of ionizing radiation. These combination spectra are the reason symbiotic stars were originally called "symbiotic". Spectral features indicating the presence of two very different types of environments in the same object made these objects seem a symbiosis of hot and cold that we now know comes from two separate stars in a binary.

2. Jets

Collimated outflows of material ("jets") have been observed from at least 10 of roughly 200 known symbiotic stars (see Brocksopp *et al.* 2003, and Corradi *et al.* 2001 for lists and references). Many of these jets are transient, and seem to appear during or after an optical outburst, or temporary brightening. They then tend to fade on time scales of months to years. Because jets may be associated with eruptions, more jets are likely to be found when other symbiotic stars go into outburst. Symbiotic jets are small in the angle they subtend on the sky (typically a few arcsec or less; see Figure 3), so they are a challenge to observe. They can either be detected directly with high-angular-resolution radio maps, or satellites such as the Hubble Space Telescope (HST) and Chandra, or their presence inferred from Doppler-shifted emission lines in optical spectra. Moreover, jet observations must be performed at the correct time, after material has been ejected, but before emission from the jet fades.

Astrophysical jets are seen in systems ranging from black holes in X-ray binaries, to pre-main-sequence stars, to active galactic nuclei. How these jets are

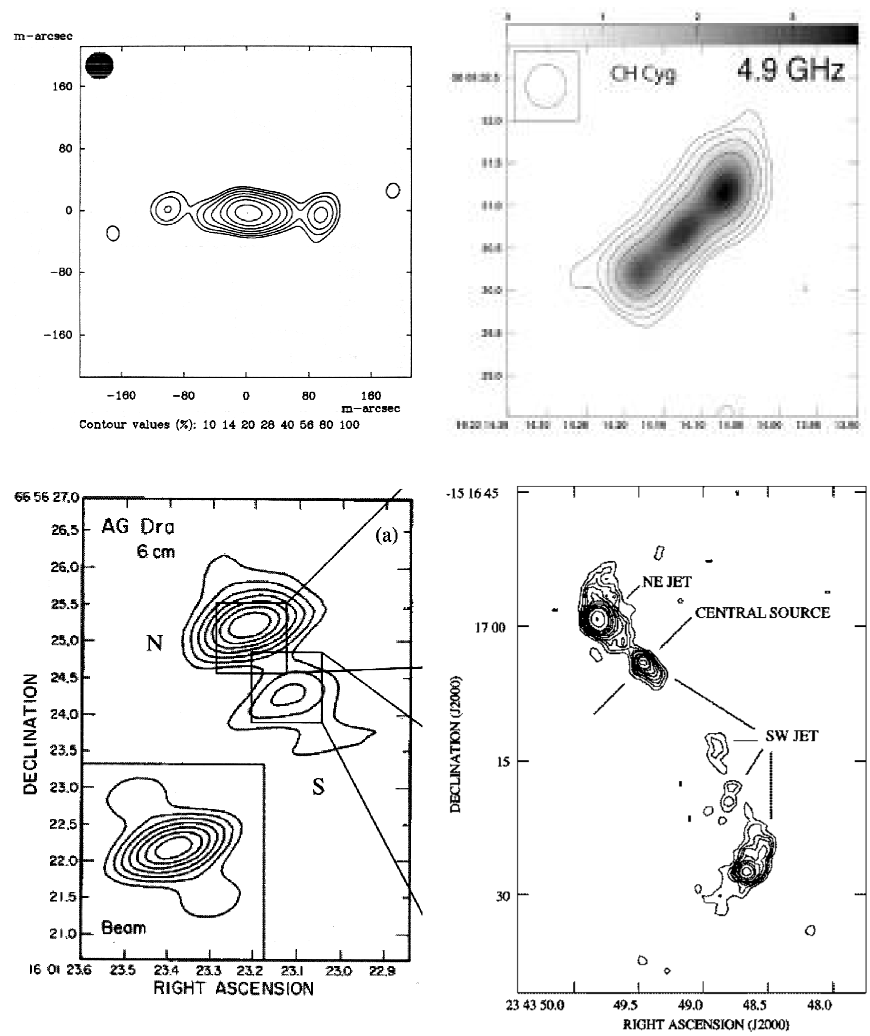

Figure 3: Four examples of symbiotic-star radio jets. Upper left: RS Oph (Taylor *et al.* 1989). Upper right: CH Cyg (Crocker *et al.* 2001). Lower left: AG Dra (Ogley *et al.* 2002). Lower right: R Aqr—the X-ray contour map is shown for this system (Kellogg *et al.* 2001). All graphs used by permission of the authors.

produced is an important unsolved problem. As in the other astrophysical jet sources, it is not fully understood how symbiotic-star jets are collimated and accelerated. The outflows are somehow linked to the process of accretion. For example, an accretion disk threaded by a magnetic field, plus some additional source of energy or wind close to the central object, may be required for jets to form (Livio 1997). If the basic ingredients for jet collimation and acceleration are the same in all cases, then the detailed investigation of one class of jet source promises to improve our fundamental understanding of the production of astrophysical jets. Symbiotic stars are likely to have accretion disks that are similar to the disks in CVs, which are among the best understood disks. In addition, symbiotics are numerous, and they are close enough for their jets to be imaged (see Figure 3). They are therefore good objects to study. Furthermore, some of the main elements apparently necessary for the generation of jets (e.g., an accretion disk, a strong white-dwarf magnetic field, and nuclear burning on the WD surface) exist in some symbiotic stars but not in others. *[Author's note: Mikołajewska (2003) has suggested that the symbiotics with accretion disks are the ones that have outbursts, and Livio (1988) described requirements for disk formation that can be used to determine which systems would be expected to contain accretion disks on theoretical grounds. For a variety of perspectives on magnetic fields in symbiotic stars and a report of the first solid detection of a strong magnetic field in a symbiotic, see Sokoloski (2003); Sokoloski, Bildsten, and Ho (2001); Sokoloski and Bildsten (1999); Mikołajewski, Mikołajewska, and Khudyakova (1990); and Tomov (2003). Finally, the luminosity of the white dwarf in a symbiotic indicates whether or not extra energy is being released by quasi-steady nuclear burning on the WD surface; estimates of these luminosities are reported by Mürset et al. (1991).]* Thus, the necessity of these elements for jet production can in principle be tested.

3. Outbursts

At least some symbiotic jets occur together with an optical outburst or change of brightness state. Therefore, investigations of jets rely on awareness of symbiotic outbursts. Moreover, understanding jet production requires knowledge of the cause of the outbursts. There are at least three types of outbursts in symbiotic stars: recurrent novae, symbiotic (or "slow") novae, and "classical symbiotic outbursts." The first two types of outbursts are believed to be due to a thermonuclear runaway on the surface of the white dwarf, as in classical novae. However, the cause of classical symbiotic outbursts, which are the most common, is not known. During a classical symbiotic outburst, the optical brightness typically increases by several magnitudes, but in some cases can increase by as little as one magnitude. The system may take weeks or months to reach maximum brightness, and then months or years to fade. These events could be due to: (a) gravitational energy release from a sudden influx of matter onto the WD due to an accretion disk instability (as in the dwarf novae CVs; see Warner 1995); (b) an expansion of the WD photosphere, shifting the high luminosity of a steady-burning WD from the UV into the visible part of the spectrum; (c) an increase in the rate of nuclear burning on the WD surface at the base of its accreted surface layers; or some combination of all of these phenomena.

The nature of symbiotic-star outbursts may also have bearing on cosmological studies of the expansion of the universe. The amount of inflow to and outflow from a WD in a symbiotic binary determines whether it can gain enough material to approach the maximum allowable mass for a WD (the Chandrasekhar limit) and then explode as a Type Ia supernova (SN Ia). SN Ia are used as “standard candles” to determine distances in cosmological studies. It is therefore important to identify their progenitor objects so that any intrinsic differences between SN Ia at different cosmic epochs can be fully taken into account. To explode as a SN Ia, the mass of an accreting WD must eventually approach the Chandrasekhar mass limit of 1.4 solar masses. But the amount of material ejected from a symbiotic WD during outburst (in the form of a jet or spherical shell) limits the degree to which the WD mass can increase during the period of active mass transfer from the red giant. Therefore, understanding the outburst mechanism(s) will help reveal the fate of symbiotic WDs, and their relation to SN Ia.

4. Observing strategy

Multi-wavelength and “Target-of-Opportunity” (TOO) observing strategies are necessary to investigate symbiotic-star outbursts and jets. The bulk of the energy produced by the hot WD in symbiotic stars is radiated at short wavelengths (primarily far ultraviolet and soft X-rays), whereas any disk emission is likely to be optical, and much of the emission from the nebula is in the optical and the radio. Furthermore, collimated jets can often only be directly detected at radio wavelengths. Therefore, observations over a broad range of wavebands are required for imaging and spectral modeling.

Target-of-Opportunity observations are planned ahead of time, and performed when a certain trigger event, such as an outburst, occurs. TOO observations are needed to study symbiotic stars because their outbursts are not predictable. TOO programs are in place for observations with the Very Large Array (VLA; radio), the Hubble Space Telescope (HST), the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite, the X-ray Multi-Mirror (XMM) satellite, and the Chandra X-ray Observatory, in addition to optical spectroscopy. However, all of these potentially important observations rely on knowing when a symbiotic star is in outburst.

5. Role of optical monitoring

Optical monitoring is important for many aspects of symbiotic star research. Long-term light curves will: 1) reveal systems in outburst; 2) enable TOO observations with the VLA, as well as HST, FUSE, and in some cases XMM and Chandra satellites; 3) determine the fraction of symbiotic stars that have outbursts; 4) determine other basic outburst statistics, such as average outburst frequencies and durations; and 5) generally characterize symbiotic-star long-term optical variability (classical symbiotic outbursts may actually encompass several different types of outbursts). Table 1 lists the symbiotic stars that are already included in the AAVSO International Database. Observations of objects from this list are welcomed and encouraged. We are working to expand the set of AAVSO symbiotics to include all symbiotic stars listed in the catalog of Belczyński *et al.* (2000). Table 2 lists objects that have not yet been added to the AAVSO database, but for which observations are needed for an X-ray program. Observers interested in these objects should contact the author directly for charts (jsokolos@cfa.harvard.edu).

6. Summary

Symbiotic stars are wide binary stars in which material is transfered to a compact white dwarf from an evolved red giant. Because of the longer variability time scale compared to CVs and the presence of a luminous nebula around the two component stars, the details of the accretion process in symbiotic stars have been more difficult to ascertain than in CVs. Thus, many interesting and fundamental open questions remain. For example, symbiotic stars appear to be a new class of jet-producing astronomical objects, but how are these jets produced? In addition, the cause of the most common type of symbiotic-star outburst is still not understood, and symbiotics may be the progenitors of the cosmologically important Type Ia supernovae. The potential value of comprehensive long-term optical monitoring of symbiotic stars provides an exciting opportunity for groups of amateurs such as the AAVSO and their professional collaborators. With enough amateur observations: 1) all outbursts can be discovered and studied, 2) outburst statistics for the whole class can be obtained and outburst classification refined, and finally, 3) the relationship between outbursts and jets can be revealed. A new program is being initiated to increase the number of symbiotic stars in the AAVSO database from roughly 70 to the full set of approximately 200. A workshop will be held at a future AAVSO meeting for those interested in learning more about symbiotic stars and how to observe them. Since long-term optical monitoring is both valuable in its own right and can lay the groundwork for additional observations, collaboration between amateurs and professionals is an excellent way to make progress in this field of study.

7. Acknowledgements

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8. Further reading

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Table 1. Symbiotic stars currently in the AAVSO International Database.

Desig.	Name	R. A. (2000) h m s	Dec. (2000) ° ′ ″	V	Coordinates Source / Comments
0039+40	EG And	00 44 37.1799	+40 40 45.838	7.1	HIP 3494
0130+53	AX Per	01 36 22.6957	+54 15 02.456	10.9	TYC 3671 247 1
0152+52	V471 Per	01 58 49.6751	+52 53 48.473	13.0	CMC 901416 few data points
0214–03	omi Cet	02 19 20.7866	–02 48 37.418	6.0	HIP 10826 Mira prototype
0515+32	UV Aur	05 21 48.9243	+32 30 40.105	8.5	TYC 2394 373 1
0517–08	V1261 Ori	05 22 18.6169	–08 39 57.986	6.8	HIP 25092 few data points
0720–03	BX Mon	07 25 22.7644	–03 35 50.424	11.7	CMC 905899
0721–07	V694 Mon	07 25 51.2856	–07 44 08.111	9.5	TYC 5396 1135 1 known jet source
0810–41	RX Pup	08 14 12.3203	–41 42 28.956	11.5	TYC 7668 2915 1
0827–27	AS 201	08 31 42.890	–27 45 31.60	11.8	USNO-A2.0 0600 -10606304 few data points
0937–48	KM Vel	09 41 13.6529	–49 23 27.798	15.0	UCAC1 11036888 few data points
1127–64A	SY Mus	11 32 09.9890	–65 25 11.582	10.9	TYC 8980 154 1
1217–62	BI Cru	12 23 25.9959	–62 38 16.012	11.1	UCAC1 04287027 check out this light curve!!
1229–64	RT Cru	12 34 53.7354	–64 33 56.091	12.6	UCAC1 03422435 few data points
1239+37	TX CVn	12 44 42.0752	+36 45 50.648	9.5	TYC 2533 1168 1
1310–36	V1044 Cen	13 16 01.6	–37 00 11.9	11.2	A&AS 146, 407 CD–368436 =NSV6160
1314–55	V840 Cen	13 20 49.401:	–55 50 14.50:	14.1	GSS [GSC 8666 -01230]
1328–24	RW Hya	13 34 18.1438	–25 22 48.987	8.9	TYC 6718 1146 1
1328–64	NSV 19878	13 35 27.5605	–64 45 44.995	12.9	UCAC1 03446120 = Hen 3-916; few data points
1408–61	V417 Cen	14 15 59.6796	–61 53 50.232	12.2	UCAC1 04818754
1411–21	IV Vir	14 16 34.2881	–21 45 49.920	10.7	TYC 6151 1012 1 =BD-21 3873
1537–66	Hen3-1092	15 47 10.6	–66 29 16.0	13.5	A&AS 146, 407 few data points

(Table 1 continued on following pages)

Table 1. Symbiotic stars currently in the AAVSO International Database, continued.

Desig.	Name	R. A. (2000) h m s	Dec. (2000) ° ′ ″	V	Coordinates Source / Comments
1544–48	NSV 20412	15 51 15.9327	–48 44 58.529	11.0	HIP 77662 = HD 330036; few data points
1555+26	T CrB	15 59 30.1650	+25 55 12.507	10.1	HIP 78322 recurrent nova
1601+67	AG Dra	16 01 41.0226	+66 48 10.187	9.1	HIP 78512 radio jet detected
1635–62	KX TrA	16 44 39.7893	–62 37 05.498	12.4	UCAC1 04373496
1645–25	NSV 20790	16 51 20.4061	–26 00 26.782	12.2	UCAC1 22568929 =AS 210; few data points
1648–30C	HK Sco	16 54 41.0412	–30 23 06.848	13.5	UCAC1 20442067
1648–30A	CL Sco	16 54 51.9704	–30 37 18.232	13.3	UCAC1 20164154
1700–33	V455 Sco	17 07 21.7369	–34 05 14.458	13.7	UCAC1 18355984 few data points
1702–17	V2523 Oph	17 08 36.6	–17 26 30.0	12.5	A&AS 146, 407 = Hen 3-1341
1734–11	RT Ser	17 39 51.9905	–11 56 38.598	15.0	CMC 1014993 slow nova; few data points
1733–47	AE Ara	17 41 04.9178	–47 03 27.197	12.5	UCAC1 12127941
1737–22	V2110 Oph	17 43 33.366	–22 45 35.91	19	USNO-A2.0 0600 -28373042 slow nova
1744–06	RS Oph	17 50 13.1626	–06 42 28.512	11.5	CMC 1110739 recurrent nova; radio jet
1745–17	ALS 2	17 50 51.1135	–17 47 57.220	14.2	UCAC1 26364569 few data points
1745–22	AS 245	17 51 00.860	–22 19 35.45	11.0	USNO-A2.0 0675 -22897072 few data points
1748–33B	V745 Sco	17 55 22.235	–33 14 58.57	17	GSS recurrent nova
1759–20	AS 270	18 05 33.7281	–20 20 38.086	13.1	UCAC1 25437415 outburst mid-2001?
1800–36	V615 Sgr	18 07 39.922	–36 06 22.13	13.3	GSS outburst late 1997?

(Table 1 continued on following pages)

Table 1. Symbiotic stars currently in the AAVSO International Database, continued.

Desig.	Name	R. A. (2000) h m s	Dec. (2000) ° ′ ″	V	Coordinates Source / Comments
1804–28	V2506 Sgr	18 11 01.679	–28 32 39.03	12.0	GSS few data points
1806–11	V343 Ser	18 12 22.153	–11 40 07.17	12.1	USNO-A2.00750 -12799421 = AS 289; few data points
1807–42	Y CrA	18 14 22.9523	–42 50 32.296	14.4	UCAC1 14276652
1810+20	YY Her	18 14 34.1747	+20 59 21.084	12.8	CMC 412559 finished outburst in June 2003
1808–29B	V2756 Sgr	18 14 35.175	–29 49 20.00	11.5	GSS
1809–00	FG Ser	18 15 07.0959	–00 18 52.107	11.0	TYC 5098 731 1
1809–30	V4074 Sgr	18 16 05.561:	–30 51 15.31:	11.5	GSS
1811–28	V2905 Sgr	18 17 20.303	–28 09 49.62	12.3	GSC 6856-01061
1810–66	AR Pav	18 20 27.8823	–66 04 42.878	10.0	HIP 89886
1815–31	V3804 Sgr	18 21 28.7799	–31 32 04.554	12.0	UCAC1 19672940
1818+23	V443 Her	18 22 07.883	+23 27 20.16	11.5	A&AS 143, 343
1819–28	V4018 Sgr	18 25 27.0	–28 35 57.5	11.4	2-mag drop started May 2000
1824–24	V3890 Sgr	18 30 43.2875	–24 01 08.901	~14	UCAC1 23612566 recurrent nova
1842–20	NSV 24592	18 47 55.8072	–20 05 50.964	12.0	UCAC1 25466410 = MWC 960; few data points
1847–24B	AS 327	18 53 16.6569	–24 22 58.767	11.8	UCAC1 23632440 few data points
1848–19	FN Sgr	18 53 54.7850	–18 59 40.668	12.7	CMC 1111581 outburst ~1995–2001
1857–17	V919 Sgr	19 03 45.1332	–16 59 55.291	12.2	CMC 917107
1859+16	V1413 Aql	19 03 46.8385	+16 26 17.110	14.0	CMC 1017292 outburst ~1993–2001
1920+29	BF Cyg	19 23 53.5039	+29 40 29.250	12.3	TYC 2137 234 1
1921+50	CH Cyg	19 24 33.0742	+50 14 29.301	7.1	HIP 95413 known jet source
1923–06	StHA 164	19 28 41.653	–06 03 51.54	13.6	A&A 372, 145

(Table 1 continued on following page)

Table 1. Symbiotic stars currently in the AAVSO International Database, continued.

Desig.	*Name*	*R. A. (2000)* *h m s*	*Dec. (2000)* *° ′ ″*	*V*	*Coordinates Source / Comments*
1937+16	HM Sge	19 41 57.0688	+16 44 39.710	17	TYC 1602 1636 1 slow nova
1932–68	NSV 12264	19 42 25.3	–68 07 35.3	10.4	A&AS 146, 407 = Hen 3-1761; outburst 1999
1941+18	QW Sge	19 45 49.548	+18 36 48.47	12.8	A&AS 143, 343 few data points
1946+35	CI Cyg	19 50 11.8360	+35 41 03.028	11.0	HIP 97594
1953+39	V1016 Cyg	19 57 05.0301	+39 49 36.162	11.2	TYC 3141 533 1 slow nova
1956–56	RR Tel	20 04 18.5345	–55 43 33.144	10.8	TYC 8780 1277 1 slow nova
2016+21	PU Vul	20 21 13.3167	+21 34 18.133	11.6	TYC 1643 1021 1 slow nova
2031+19	LT Del	20 35 57.234	+20 11 27.91	13.1	A&AS 143, 343 few data points
2037+08	ER Del	20 42 46.4962	+08 41 13.438	10	TYC 1089 194 1
2047+35	V1329 Cyg	20 51 01.279	+35 34 54.59	13.3	USNO-A2.0 1200 -16192521 slow nova; jet source
2053–43	CD–43 14304	21 00 06.3593	–42 38 44.899	10.8	UCAC1 14307392 observations greatly needed
2058+45	V407 Cyg	21 02 09.831	+45 46 32.85	14	A&AS 143, 343 outburst ~1998–2003
2146+12	AG Peg	21 51 01.9747	+12 37 32.137	9.0	HIP 107848 slow nova
2328+48	Z And	23 33 39.9565	+48 49 06.001	10.8	HIP 116287 class prototype; radio jet
2136+02	NSV 25735	21 41 44.8	+02 43 54.4	10.5	A&AS 146, 407 = StHa 190; few data points
2328–15	R Aqr	23 43 49.4416	–15 17 03.917	9.1	HIP 117054 known jet source; Mira red giant

(Table 1 continued on following page)

Table 1. Symbiotic stars currently in the AAVSO International Database, continued.

The AAVSO light curve for each object in this table may be found on the AAVSO light-curve-generator website: http://www.aavso.org/data/lcg/. Objects and V magnitudes taken from Belczyński et al. *(2000) who state: "As most (if not all) symbiotics are variable, these values are arbitrary (usually the average of published measurements) just to give the general level of an object's brightness." For background on individual objects, see Belczyński* et al. *(2000) or Kenyon (1986).*

Coordinates (except those from A&AS 146, 407) were assembled and verified by R. Webbink. They are drawn (in priority order) from The Hipparcos *(HIP) and* Tycho *(TYC) catalogs (Perryman* et al. *1997),* U.S. Naval Observatory CCD Astrographic Catalog *(UCAC1) (Zacharias* et al. *2000),* Carlsberg Meridian Catalog *(CMC) (Copenhagen U. Obs.* et al. *1999), astrometry by Henden and Munari (2000, 2001), the* U.S. Naval Observatory A2.0 Catalog *(USNO-A2.0) (Monet,* et al. *1998),* Guide Star Catalog *1.1 (GSC) (Space Tel. Sci. Inst. 1992), and from R. Webbink's measurements in the GSC frame on the* Guide Star Survey *using the STScI GASP software (Space Tel. Sci. Inst. 2003).*

Table 2. X-Ray bright symbiotics soon to be added to the AAVSO International Database.

Name	*R. A. (2000)* h m s	*Dec. (2000)* ° ′ ″	*V*	*Coordinates Source / Comments*
SMC3	00 48 20.186	–73 31 51.59	15.5	GSS = [HFP2000] 512
LN 358	00 59 12.2548	–75 05 17.686	15.2	UCAC1 00750059 = SMC LN 358
LMC S63	05 48 43.4158	–67 36 10.264	15.2	UCAC1 02294530 = AL 427 = V4435 LMC
Draco C-1	17 19 57.661	+57 50 05.74	17	A&AS 143, 343 = [ALS82] C1 = V225 Dra
Hen 3-1591	18 07 32.030	–25 53 43.69	12.5	GSC 6846-00296 = NSV 10219

V magnitudes taken from Belcźynski et al. *(2000) as described in Talbe 1 notes. Coordinates were assembled and verified by R. Webbink. Sources of coordinates are as described in Table 1 notes.*